

UDC 530.122

Regular Black Holes from Gravitational Collapse of Dust and Radiation

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Abstract. A black hole is commonly understood as the end state of the gravitational collapse of a massive star. According to Penrose singularity theorem, under the assumption of strong energy conditions, such a process inevitably leads to the formation of a singularity. However, the presence of a singularity suggests that general relativity fails to adequately describe spacetime near ultra-compact objects. Consequently, significant attention has recently been directed toward regular black holes, in which the central singularity is replaced by a de Sitter core. This modification violates the strong energy condition but avoids singular behavior in the centre. The existence of exotic matter at the core of a regular black hole is inevitable, yet its nature remains unknown. Models based on nonlinear electrodynamics have gained popularity as sources for de Sitter cores. However, Bronnikov's theorem demonstrates that nonlinear electrodynamics can serve as a source for a de Sitter core only in the absence of an electric field, implying that such cores correspond to magnetic monopoles. Massive stars, composed of ordinary matter, do not inherently contain exotic matter that prevents singularity formation. Therefore, it is reasonable to assume that such matter arises dynamically during gravitational collapse. This work proposes a mechanism explaining how ordinary matter transitions into a state capable of forming regular cores. At critical densities during gravitational collapse, phenomena analogous to those in the early Universe may occur, including the conversion of matter into radiation. As shown in this study, when accounting for inhomogeneity and enhanced effects toward the center of a collapsing star, the outcome of gravitational collapse can be a regular black hole. This process provides a plausible explanation for well-known regular black hole models, such as those proposed by Bardeen, Hayward, and Dymnikova.